Smoking Cessation Interventions After Lung Cancer Screening Guideline Change

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Introduction: Recent guideline changes for lung cancer screening with low-dose computed tomography recommend smoking cessation interventions be done in parallel with screening. The purpose of this study is to determine the post-guideline rates of smoking cessation interventions among patients eligible and ineligible for lung cancer screening.

Methods: Using electronic health records collected from a large ambulatory care system in northern California between 2010 and 2017, authors identified new patients who were current smokers aged 55–80 years visiting a primary care provider, and grouped patients into lung cancer screening–eligible heavy smokers, screening-ineligible moderate smokers, and screening-ineligible light smokers. Screening-eligible smokers versus screening-ineligible smokers were compared in receipt of smoking cessation interventions before (2010–2013) and after (2014–2017) the guideline change, overall and by intervention type (formal counseling, informal counseling, pharmacotherapy) using hierarchical generalized linear models. Analyses were conducted in 2018–2019.

Results: After the guideline change, the likelihood of receiving any smoking cessation intervention (OR=1.44, 95% CI=1.28, 1.61, $p<0.05$), informal counseling (OR=1.29, 95% CI=1.15, 1.46, $p<0.05$), and pharmacotherapy (OR=1.24, 95% CI=1.02, 1.50, $p<0.05$) during a new patient visit significantly increased, with the increase not varying by level of smoking. For formal counseling, the post-guideline increase was greater for screening-

eligible heavy smokers (OR=3.15, 95% CI=1.18, 8.36, $p<0.05$) and moderate smokers (OR=3.58, 95% CI=1.29, 9.95, $p<0.05$) relative to light smokers. **Conclusions:** Smoking cessation interventions increased after new lung cancer screening guidelines. Given the sizable adverse impacts of smoking on morbidity and mortality, small increases in implementation of smoking cessation interventions could have substantial public health benefits.

INTRODUCTION

Despite declining rates of smoking in recent decades, smoking remains the leading contributor to preventable disease and death in the U.S. The Surgeon General estimates that 87% of deaths from lung cancer are directly attributable to smoking.[1] Further, smoking has been shown to increase the risk of cardiovascular disease, stroke, respiratory disease, and numerous cancers.[2,3] With the public health impact of smoking continuing, in 2013 the U.S. Preventive Services Task Force (USPSTF) recommended low-dose computed tomography for lung cancer screening (LDCT-LCS) for current or recent smokers aged 55–80 years with 30 or more pack years of smoking history.[4] In addition, the guidelines recommend smoking cessation interventions be done in parallel with screening.[4–10]

With regard to smoking cessation interventions, the USPSTF specifically recommends that “clinicians ask all adults about tobacco use, advise them to stop using tobacco, and provide behavioral interventions and FDA-approved pharmacotherapy [(e.g., bupropion, nicotine-replacement therapy)] for cessation to adults who use tobacco.”[11] Each approach is well established and has been proven individually effective,[12–14] and using various combined approaches, such as physician counseling with pharmacotherapy, can increase the probability of cessation—up to 82% in one study[15]—versus a single approach.[16–18] Nevertheless, reported rates of smoking cessation interventions by primary care providers (PCPs) vary greatly, with PCPs citing

lack of insurance coverage, time constraints, patient readiness to quit, and their own limited self-efficacy in counseling and knowledge about supporting therapies (e.g., behavioral interventions and medications) as barriers to providing smoking cessation interventions.[19–22] Among smokers of all ages in the U.S., the number of patients reporting smoking cessation advice from healthcare professionals has been increasing since 2010, reaching 57.2% by 2015. The use of cessation counseling or medication among smokers who were trying to quit, however, did not rise between 2010 (31.7%) and 2015 (31.2%).[23] This is concerning because more than 40% of smokers are not currently receiving any cessation support from healthcare professionals.

The purpose of this study is to assess the provision of smoking cessation interventions before (2010–2013) and after (2014–2017) the USPSTF recommended LDCT-LCS along with smoking cessation interventions. Preliminary data from the studied healthcare system show that both LDCT-LCS orders[24] and shared decision-making visits for LDCT-LCS increased after USPSTF guidelines. The expectation is that measures of smoking cessation interventions would also change. LDCT-LCS guidelines have likely: (1) increased the documentation of smoking history (impacting the number of patients considered eligible for various interventions) and (2) led to a renewed focus on smoking cessation. This paper compares the rate of change in smoking cessation interventions between LCS-eligible and -ineligible smokers pre- and post-guideline. The authors hypothesize that all

cessation interventions increased after the USPSTF recommended LDCT-LCS, with a steeper increase among LCS-eligible smokers than LCS-ineligible smokers.

METHODS

Study Sample

This study was a retrospective analysis using electronic health record (EHR) data from a large healthcare system in northern California. The analysis focused on patients new to the system aged 55–80 years, visiting a family medicine or internal medicine PCP between January 1, 2010 and December 31, 2017, and who were identified as current smokers with no evidence of lung cancer based on encounter diagnosis or problem list history. The target age, 55–80 years, is in line with the LDCT-LCS guidelines recommendations from the USPSTF.[4] The focus on “new patient visits” to a PCP (not necessarily a visit for LDCT-LCS) in the healthcare system was because such visits are typically scheduled for a longer period of time than acute care or follow-up visits. Focusing just on “new patients” eliminates situations in which the PCP may have had previous discussions with the patient about their smoking. Determination of LCS eligibility requires calculation of “pack years,” defined as the number of packs of cigarettes smoked per day multiplied by the number of years the person has smoked (e.g., 1 pack-year=smoking 1 pack per day for 1 year). Not infrequently, the medical record for new patient visits with a current smoker did not contain enough information to calculate

pack years. Excluding those visits (*n*=7,184) in which eligibility for LDCT-LCS could not be determined owing to lack of sufficient information on smoking history, 63.8% of 19,862 (*n*=12,678) current smokers were included in the analysis. In addition, light smoking was defined as smoking fewer than ten cigarettes per day, which is consistent with the definition of light smoking in the *Treating Tobacco Use and Dependence: 2008 Update*—Clinical Practice Guideline.[25] Current smokers were then classified as: (1) LCS-eligible heavy smokers (≥30 pack years), (2) LCS-ineligible moderate smokers (<30 pack years and ten or more cigarettes per day), and (3) LCS-ineligible light smokers (<30 pack years and fewer than ten cigarettes per day).

Measures

Three types of smoking cessation interventions (i.e., formal in-visit smoking cessation counseling, informal smoking cessation counseling or referrals to smoking cessation programs, and medication orders for pharmacotherapy) were considered. “Tobacco Cessation Counseling” is one of the quality metrics routinely assessed and thus is frequently noted in the EHR, but most such counseling does not meet the requirements for separate billing. An internal EHR data analyst reviewed a random sample of physician’s notes and confirmed that the quality metric of “Tobacco Cessation Counseling” is a reliable indicator for in-visit smoking cessation counseling. Keyword searches included, but were not limited to, *smoking cessation* and *tobacco counseling* in the procedure description. Sessions of 3–10 minutes or >10 minutes (e.g.,

billing codes: 99406, G0375, G0376; 99407, G0436, G0437) were classified as “formal in-visit smoking cessation counseling.” Smoking cessation counseling <3 minutes is not separately billed; such unbilled in-visit smoking cessation counseling, along with referrals for internal free smoking cessation programs, are categorized as “informal smoking cessation counseling or referrals to smoking cessation programs.” Pharmacotherapy using smoking deterrents was identified by a prescription order for smoking cessation medication, (e.g., bupropion HCL, varenicline tartrate, nicotine polacrilex).

The two key explanatory variables are “guideline change” (pre-guideline: 2010–2013 and post-guideline: 2014–2017) and “level of smoking” (1=LCS-eligible heavy smoker, 2=LCS-ineligible moderate smoker, 3=LCS-ineligible light smoker). In a supplemental analysis, the authors linked “Receiving LDCT-LCS referral at the same visit (yes/no)” to smoking cessation interventions.

Statistical Analysis

First, patient demographic, smoking history, and smoking cessation intervention variables by time and level of smoking were compared using ANOVA for continuous variables or Pearson’s chi-square test for categorical variables. Next, for each of the three groups, the percentage who received each of the smoking cessation interventions before (2010–2013) and after (2014–2017) guideline implementation was compared using Pearson’s chi-

square test. Annual rates of cessation interventions for LCS-eligible smokers versus the two groups of LCS-ineligible smokers were plotted for comparison.

The authors also examined the association between guideline change, level of smoking, and smoking cessation intervention, employing hierarchical generalized linear models where patients (Level 1) were nested within PCP (Level 2) controlling for patient demographics (age, sex, race/ethnicity) (Model A). Next, an interaction term for guideline change and level of smoking was added to assess differential rates of change in smoking cessation intervention based on level of smoking (Model B). The same set of models were built for each outcome using either LCS-ineligible light smokers or LCS-ineligible moderate smokers as the reference group to compare LCS-eligible heavy smokers with each of the other levels. In the supplemental analysis, the authors examined the association between guideline change, receiving LDCT-LCS referral, and smoking cessation interventions, employing plot charts and hierarchical generalized linear models where patients (Level 1) were nested within PCP (Level 2) controlling for patient demographics (age, sex, race/ethnicity). All analyses were conducted in 2018 and 2019, and performed using SAS, version 9.4. This work was reviewed and approved by the Sutter Health Institutional Review Board and granted a Waiver of Health Insurance Portability and Accountability Act Authorization and a Waiver of Consent as a data-only study.

RESULTS

The study population was primarily non-Hispanic white (71%) and female (52%). Roughly 61% were aged 55–64 years and 33% aged 65–74 years (Table 1). Forty-two percent were moderate smokers; of the remainder, LCS-eligible heavy smokers (36%) were more prevalent than LCS-ineligible light smokers (21%) (Table 1). Consistent with nationwide trends,[26] there was a general downward trend in the proportion of heavy smokers (39% to 35%) and an upward trend in the proportion of light smokers (19% to 23%). Overall, 0.2% received LDCT-LCS referrals pre-guideline versus 2.7% post-guideline ($p<0.0001$), and 31% received some smoking cessation interventions pre-guideline versus 33% post-guideline ($p<0.05$) (Table 1). By intervention type, there was an increase from pre- to post-guideline in formal smoking cessation counseling (0.9% to 2.7%, $p<0.0001$) and medication orders for pharmacotherapy (4.3% to 5.2%, $p<0.05$).

Comparing the patient characteristics across level of smoking (Appendix Table 1), the light smoker group had a higher proportion of individuals who were younger ($p<0.0001$), female ($p<0.0001$), and of racial/ethnic minorities ($p<0.0001$) than heavy smokers. More than one third (36%) of heavy smokers smoked 40–49 pack years, slightly more than half (53%) of moderate smokers smoked <20 pack years, and 67% of light smokers smoked <10 pack years. The average pack years for heavy, moderate, and light smokers was 48.3 (SD=23.1), 16.9 (SD=6.8), and 7.1 (SD=4.4),

respectively. From 2010 to 2017, LDCT-LCS orders were received by 2.7% of LCS-eligible heavy smokers, 1.1% of LCS-ineligible moderate smokers, and 0.8% of LCS-ineligible light smokers. Overall, 32% of all smokers received some cessation interventions, 27% received informal smoking cessation counseling or referrals to smoking cessation programs, 1.9% received formal smoking cessation counseling, and 4.8% received pharmacotherapy. The proportion of heavy smokers with pharmacotherapy was significantly higher than that of light smokers ($p<0.0001$). There was no significant difference in proportion of smokers receiving other types of intervention or any type of intervention across three groups.

As shown in Table 2, the proportion of smokers receiving any smoking cessation intervention increased post-guideline: LCS-eligible heavy smokers (30.1% to 34%), moderate smokers (31.1% to 31.4%), and light smokers (30.4% to 33.4%). The types of intervention, however, differed across smoking category. The proportion of smokers receiving formal smoking counseling increased nearly fourfold (from lower base rates) among both heavy smokers (0.9% to 3.4%, $p<0.0001$) and moderate smokers (0.6% to 2.6%, $p<0.0001$) versus a smaller increase among light smokers (1.5% to 2.1%, $p=0.29853$). Informal smoking cessation counseling—by far the most common intervention—was essentially flat for heavy and moderate smokers, but increased from 26.4% to 29.1% among the light smokers, although not statistically significant ($p=0.13137$). Heavy smokers had the highest base

rates and increases for medication prescriptions (5.2% to 6.9%, p=0.01902); moderate smokers also saw a small increase (3.5% to 4.7%, p=0.03889), but there was a decrease for light smokers (4.0% to 3.8%, p=0.8485). Figure 1 depicts the annual trends among new patients by level of smoking in percentages receiving smoking cessation interventions. There was prominent fluctuation in unbilled, informal counseling among light smokers relative to heavy and moderate smokers. The proportion of heavy smokers receiving formal smoking counseling has been increasing since 2010 and it accelerated after 2015. The moderate smoker group rate also picked up after 2016. There was a downward trend in cessation medication prescriptions for heavy smokers until 2013, then a reversal to an upward trend. The reverse appeared for light smokers—an upward trend until 2013, then roughly flat. Moderate smokers exhibited no discernable trend.

After controlling for age, sex, race/ethnicity, and level of smoking, there were significant increases after the guideline change in the likelihood of receiving any smoking cessation intervention (OR=1.44, 95% CI=1.28, 1.61, p<0.05), informal counseling (OR=1.29, 95% CI=1.15, 1.46, p<0.05), and pharmacotherapy (OR=1.24, 95% CI=1.02, 1.50, p<0.05). There was no difference, however, in the trend based on smoking level (Table 3). For formal counseling, the post-guideline increase was greater (indicated by the interaction between guideline change and level of smoking) for LCS-eligible

heavy smokers (OR=3.15, 95% CI=1.18, 8.36, $p<0.05$) and moderate smokers (OR=3.58, 95% CI=1.29, 9.95, $p<0.05$) than light smokers.

As shown in Appendix Figure 1 and Appendix Table 2, the smokers that were newly seen by a PCP and who received a referral for LDCT-LCS at the same visit were more likely to receive informal counseling (OR=1.52, 95% CI=1.08, 2.14, $p<0.05$), formal counseling (OR=3.58, 95% CI=1.68, 7.61, $p<0.05$), pharmacotherapy (OR=3.17, 95% CI=2.06, 4.9, $p<0.05$), and any smoking cessation intervention (OR=2.26, 95% CI=1.63, 3.12, $p<0.05$), controlling for time, age, sex, and race/ethnicity. Note that Hispanic patients were less likely than non-Hispanic whites to receive formal counseling (OR=0.54, 95% CI=0.3, 0.95, $p<0.05$) and non-Hispanic Asians were less likely than non-Hispanic whites to receive medication orders for pharmacotherapy (OR=0.51, 95% CI=0.33, 0.81, $p<0.05$), controlling for all other factors.

DISCUSSION

This study is among the first to examine the implementation of smoking cessation interventions by level of smoking among older patients after the new LDCT-LCS guidelines in 2013. The likelihood of receiving any smoking cessation intervention significantly increased after 2013, irrespective of level of smoking. The differential change by level of smoking was more pronounced for formal smoking cessation counseling during a visit. For heavy

and moderate smokers, formal cessation counseling rates increased more than fourfold after the guideline implementation versus a smaller increase for light smokers.

When the LDCT-LCS program started in 2013, presentations for PCPs at all the major clinic sites in the healthcare system reviewed the results of National Lung Screening Trial[27] and the guidelines, and discussed the need for shared decision making and patient selection as well as smoking cessation and appropriate follow-up per Lung CT Screening Reporting & Data System (Lung-RADS). However, LDCT-LCS is a complex process including multiple components and carries potential risks,[27,28] so the implementation of LDCT-LCS faces barriers at patient,[29,30] provider,[31–36] and healthcare system levels.[37] Therefore, awareness of the new LDCT-LCS guidelines may not necessarily have led to LDCT-LCS screening in specific cases, but may have led to an increased cessation effort on the part of physicians. For coverage of LDCT-LCS, Medicare requires smoking cessation interventions be performed in conjunction with screening.[10] The LDCT-LCS rate was steadily increasing, but was far lower than the incidence of cessation interventions.[24]

The temporal change in smoking cessation intervention incidence observed in this study may also be attributable to factors beyond the LDCT-LCS guideline implementation. One potential contributor is the re-released USPSTF recommendation in 2015 for clinicians to offer cessation support to

smokers.[11] This, however, is less likely to have a “differential” impact by level of smoking. Other than the presentations associated with the LDCT-LCS guideline recommendations in 2013, there were no efforts in the healthcare system specifically targeting tobacco treatment during 2010–2017. Thus, the implementation of the screening guideline is a plausible explanation for the observed differential trend in smoking cessation intervention based on level of smoking. Furthermore, the supplemental study results indicate that there are positive relationships between LDCT-LCS referral and smoking cessation interventions.

It is well established that healthcare providers should play a key role in fighting tobacco use.[14] Previous work has shown more than 80% of smokers visit a PCP each year,[38] and physician advice has been estimated to increase cessation rates by about 30%.[39] With more than 65% of smokers having expressed an interest in quitting,[23,40] if, as a result of physician advice, those smokers try to quit and even a small percentage succeed in complete abstinence,[14] this may decrease morbidity and mortality among smokers and the public health burden of smoking.[41] Recommendations have pointed out the importance of providing smoking cessation interventions specifically within the context of the LDCT-LCS environment.[42,43]

Importantly, this work focused on older smokers who meet the age criteria of 55–80 years for LDCT-LCS. The 2015 National Health Interview Survey

indicates that older smokers have less interest in quitting smoking and report fewer past-year quit attempts than younger smokers.[23] Thus, the lower rates of smoking cessation interventions among current smokers aged 55–80 years[23] may reflect “hard-to-convince” long-time smokers who are unable or unwilling to participate in smoking cessation interventions.[42,44,45] However challenging, the effort is worthwhile—older adults are more likely to have aging-related medical illnesses that may be exacerbated by smoking.[1] Previous reviews have suggested that the older smokers respond to smoking cessation interventions at similar rates to younger smokers and that cessation brings health benefits.[46,47] The observed increase, albeit small (from 31% to 33%), in smoking cessation interventions among smokers aged 55–80 years during new patient visits after the guideline change is encouraging. Moreover, there was a statistically significant increase in formal smoking cessation counseling and medication orders for pharmacotherapy. Both receipt of intensive smoking cessation counseling and pharmacotherapy can improve quit rates[12–14] and this finding in older smokers is particularly important.

Limitations

The authors recognize several limitations. First, the data come from a single healthcare organization whose primary care base reflects a relatively well-insured patient population. However, the organization covers a substantial geographic area that includes low-income, rural, non-English speaking, and

minority patients reflecting the population of California. Second, EHR structured fields may not have captured all informal counseling sessions and referrals. Additionally, many smoking cessation medications can be purchased over the counter without prescription, so those obtaining these medications on their own may not be recorded in the EHR. Third, it was not possible to distinguish the effects of the guidelines per se from other time-related factors (e.g., the re-released USPSTF recommendation for smoking cessation in 2015[11]) that may lead to increased smoking cessation interventions over time. However, no other factors have been found to explain the differential effects by level of smoking. The LDCT-LCS guideline that focuses on heavy smokers is a plausible explanation for the steeper rise in formal counseling among LCS-eligible heavy smokers than LCS-ineligible light smokers.

CONCLUSIONS

Discussing LDCT-LCS may provide a teachable moment to promote tobacco cessation.[48,49] The findings of this study highlight how the requirement to integrate smoking cessation interventions as part of the LDCT-LCS process may have improved physician-administered cessation efforts more broadly. Further work should be done to examine the mechanism(s) through which this happened and whether these increased efforts result in any measurable reduction in smoking rates and long-term abstinence. Given the dramatic benefits of smoking cessation on reducing mortality, even a modest increase

in implementation of smoking cessation interventions and potentially modest success of quitting after intervention would imply substantial public health benefits.

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LIST OF FIGURES

LCS, lung cancer screening.

Table 1. Characteristics of New Patients (N=12,678), 55–80 Years Old, Currently Smoking, 2010–2017

Individual-level variables	**All (N=12,678)**	**Pre-guideline 2010–2013 (n=5,580)**	**Post-guideline 2014–2017 (N=7,098)**	***p*-value**
	N (%)	**N (%)**	**N (%)**	
Age, years				0.24606
55–64	7,695 (60.7)	3,343 (59.9)	4,352 (61.3)	
65–74	4,183 (33.0)	1,884 (33.8)	2,299 (32.4)	
75–80	800 (6.3)	353 (6.3)	447 (6.3)	
Female	6,635 (52.3)	2,977 (53.4)	3,658 (51.5)	**0.04217**
Race/ethnicity				**0.00002**
Missing	1,084 (8.6)	489 (8.8)	595 (8.4)	
NH white	8,959 (70.7)	4,038 (72.4)	4,921 (69.3)	
Hispanic	974 (7.7)	388 (7.0)	586 (8.3)	
NH black	750 (5.9)	278 (5.0)	472 (6.6)	
NH Asian	525 (4.1)	230 (4.1)	295 (4.2)	
Other	386 (3.0)	157 (2.8)	229 (3.2)	
Level of smoking				**<0.0001**
LCS-eligible heavy smokers	4,619 (36.4)	2,170 (38.9)	2,449 (34.5)	
LCS-ineligible moderate smokers	5,346 (42.2)	2,349 (42.1)	2,997 (42.2)	
LCS-ineligible light smokers	2,713 (21.4)	1,061 (19.0)	1,652 (23.3)	
Receiving LCS-LDCT	204 (1.6)	9 (0.2)	195 (2.7)	**<0.00**

referral				**01**
Informal smoking cessation counseling or referrals to smoking cessation programs	3,429 (27.0)	1,513 (27.1)	1,916 (27.0)	0.878 81
Formal smoking cessation counseling	243 (1.9)	49 (0.9)	194 (2.7)	**<0.00 01**
Medication orders for pharmacotherapy	609 (4.8)	238 (4.3)	371 (5.2)	**0.011 96**
Receiving any smoking cessation intervention(s)	4,031 (31.8)	1,708 (30.6)	2,323 (32.7)	**0.011 01**
Pack-years categories				**<0.00 01**
<10	2,536 (20.0)	1,008 (18.1)	1,528 (21.5)	
10–19	3,023 (23.8)	1,258 (22.5)	1,765 (24.9)	
20–29	2,500 (19.7)	1,144 (20.5)	1,356 (19.1)	
30–39	1,399 (11.0)	637 (11.4)	762 (10.7)	
40–49	1,639 (12.9)	769 (13.8)	870 (12.3)	
50–59	749 (5.9)	349 (6.3)	400 (5.6)	
>60	832 (6.6)	415 (7.4)	417 (5.9)	
Pack-years, mean (SD)	26.2 (22.6)	27.7 (23.5)	25.1 (21.7)	**<0.00 01**
Cigarettes per day, mean (SD)	14.7 (10.2)	15.2 (10.5)	14.2 (9.9)	**<0.00 01**
Number of years smoked, mean (SD)	34.6 (13.9)	35.2 (13.9)	34.0 (13.9)	**<0.00 01**

Note: Boldface indicates statistical significance ($p<0.05$).

LCS, lung cancer screening; NH, non-Hispanic; LDCT, low-dose computed tomography.

Table 2. Differences in Percent Receiving Smoking cessation interventions by Level of Smoking and Time

Variable	**LCS-eligible heavy smokers**			**LCS-ineligible moderate smokers**			**LCS-ineligible light smokers**		
	Pre-guideline	**Post-guideline**	***p*-value**	**Pre-guideline**	**Post-guideline**	***p*-value**	**Pre-guideline**	**Post-guideline**	***p*-value**
	N (%)	**N (%)**		**N (%)**	**N (%)**		**N (%)**	**N (%)**	
Informal smoking cessation counseling or referrals to smoking cessation programs	568 (26.2)	649 (26.5)	0.8021	665 (28.3)	787 (26.3)	0.09437	280 (26.4)	480 (29.1)	0.13137
Formal smoking cessation counseling	19 (0.9)	83 (3.4)	**<0.0001**	14 (0.6)	77 (2.6)	**<0.0001**	16 (1.5)	34 (2.1)	0.29853
Medication orders for pharmacotherapy	113 (5.2)	168 (6.9)	**0.01902**	83 (3.5)	140 (4.7)	**0.03889**	42 (4)	63 (3.8)	0.8485
Receiving any smoking cessation intervention(s)	654 (30.1)	832 (34)	**0.00536**	731 (31.1)	940 (31.4)	0.84785	323 (30.4)	551 (33.4)	0.11339

Note: Boldface indicates statistical significance ($p<0.05$).

LCS, lung cancer screening.

Table 3. ORs of Receiving Smoking cessation interventions Before (2010–2013) and After (2014–2017) Guideline Change[a]

Variable	**Informal smoking cessation counseling or referrals to smoking cessation programs**		**Formal smoking cessation counseling**		**Medication orders for pharmacotherapy**		**Receiving any smoking cessation intervention(s)**	
	Model A[b]	**Model B**	**Model A**	**Model B[b]**	**Model A[b]**	**Model B**	**Model A[b]**	**Model B**
	OR (95% CI)	**OR (95% CI)**	**OR (95% CI)**	**OR (95% CI)**	**OR (95% CI)**	**OR (95% CI)**	**OR (95% CI)**	**OR (95% CI)**
Level of smoking (ref=light smokers)								
LCS-eligible heavy smokers vs LCS-ineligible light smokers	0.96 (0.84, 1.1)	1.05 (0.85, 1.29)	**1.81 (1.16, 2.84)**	0.77 (0.34, 1.77)	**1.68 (1.31, 2.16)**	1.37 (0.94, 2.01)	1.09 (0.96, 1.24)	1.06 (0.87, 1.29)
LCS-ineligible moderate smokers vs LCS-ineligible light smokers	0.98 (0.86, 1.11)	1.17 (0.96, 1.44)	1.39 (0.89, 2.18)	0.53 (0.22, 1.28)	1.02 (0.79, 1.31)	0.79 (0.53, 1.17)	1.00 (0.88, 1.13)	1.07 (0.88, 1.30)
Guideline change								
Post- vs pre-guideline	**1.29 (1.15, 1.46)**	**1.55 (1.24, 1.95)**	**5.03 (3.05, 8.30)**	1.92 (0.83, 4.47)	**1.24 (1.02, 1.50)**	0.92 (0.60, 1.40)	**1.44 (1.28, 1.61)**	**1.48 (1.19, 1.83)**

Guideline change level of smoking								
Post- vs pre-guideline, LCS-eligible heavy smokers vs LCS-ineligible light smokers		0.87 (0.66, 1.14)		**3.15 (1.18, 8.36)**		1.39 (0.85, 2.28)		1.06 (0.82, 1.37)
Post- vs pre-guideline, LCS-ineligible moderate smokers vs LCS-ineligible light smokers		0.73 (0.56, 1.01)		**3.58 (1.29, 9.95)**		1.51 (0.90, 2.53)		0.89 (0.69, 1.14)
	Model A[b]	**Model B**	**Model A**	**Model B[b]**	**Model A[b]**	**Model B**	**Model A[b]**	**Model B**
	OR (95% CI)	**OR (95% CI)**	**OR (95% CI)**	**OR (95% CI)**	**OR (95% CI)**	**OR (95% CI)**	**OR (95% CI)**	**OR (95% CI)**
Level of smoking (ref=moderate smokers)								
LCS-eligible heavy smokers vs LCS-ineligible moderate smokers	0.98 (0.88, 1.10)	0.89 (0.76, 1.05)	1.30 (0.91, 1.86)	1.45 (0.66, 3.20)	**1.66 (1.36, 2.02)**	**1.75 (1.28, 2.38)**	1.09 (0.98, 1.21)	0.99 (0.85, 1.15)
LCS-ineligible light smokers vs LCS-ineligible moderate	1.02 (0.90,	0.85 (0.69,	0.72 (0.46,	1.88 (0.78,	0.98 (0.76,	1.27 (0.85,	1.00 (0.89,	0.94 (0.77,

smokers	1.17)	1.05)	1.13)	4.50)	1.27)	1.90)	1.13)	1.14)
Guideline change								
Post- vs pre-guideline	**1.29 (1.15, 1.46)**	1.14 (0.96, 1.34)	**5.03 (3.04, 8.30)**	**6.89 (3.30, 14.36)**	**1.24 (1.02, 1.50)**	**1.39 (1.02, 1.88)**	**1.44 (1.28, 1.61)**	**1.31 (1.12, 1.53)**
Guideline change level of smoking								
Post- vs pre-guideline, LCS-eligible heavy smokers vs LCS-ineligible moderate smokers		1.19 (0.95, 1.48)		0.88 (0.36, 2.13)		0.92 (0.62, 1.37)		1.20 (0.97, 1.47)
Post- vs pre-guideline, LCS-ineligible light smokers vs LCS-ineligible moderate smokers		1.37 (0.99, 1.77)		**0.28 (0.10, 0.78)**		0.66 (0.40, 1.11)		1.13 (0.88, 1.44)

Notes: Boldface indicates statistical significance ($p<0.05$). Model A: hierarchical generalized linear models where patients (Level 1) were nested within PCP (Level 2) to test main effects of guideline change and level of smoking. Model B added an interaction for guideline change and level of smoking to Model A to assess a differential change in smoking cessation intervention based on level of smoking.

[a]Patient demographics (age, sex, race/ethnicity) are controlled for in each model.
[b]Final model.

LCS, lung cancer screening.

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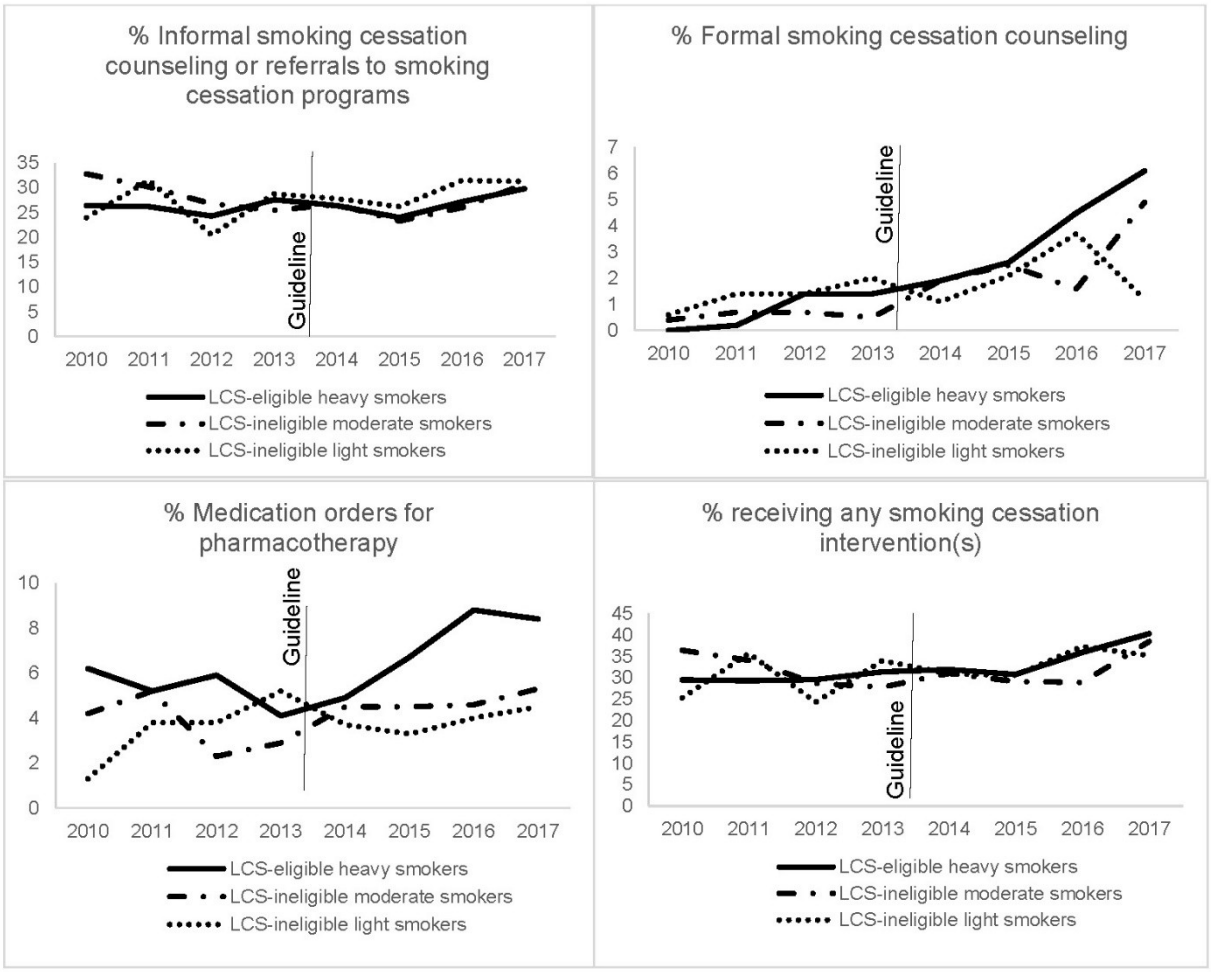
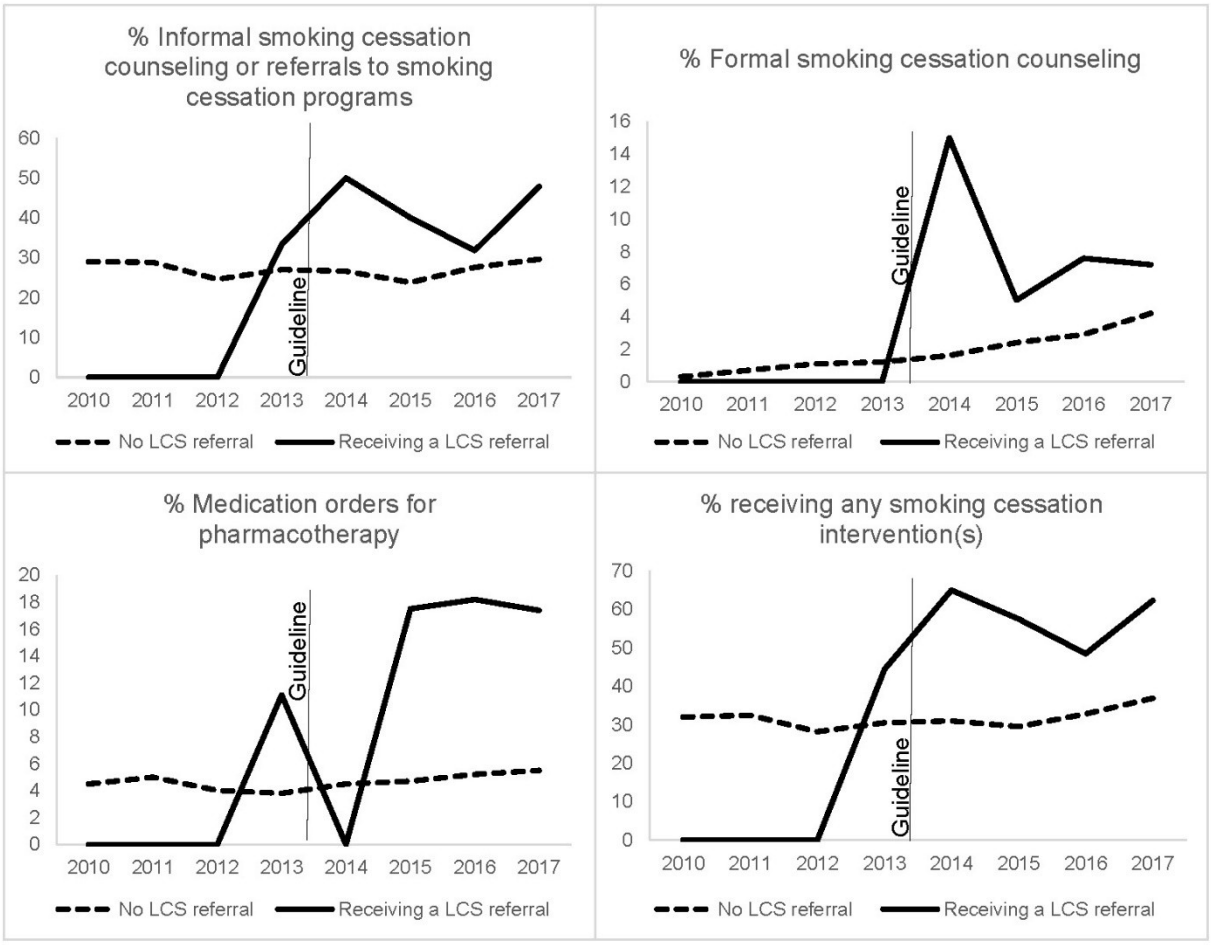

% Informal smoking cessation counseling or referrals to smoking cessation programs
35
30
25
20
15
10
5
0
Guideline
2010 2011 2012 2013 2014 2015 2016 2017
LCS-eligible heavy smokers
LCS-ineligible moderate smokers
LCS-ineligible light smokers
% Formal smoking cessation counseling
7
6
5
4
3
2
1
0
Guideline
2010 2011 2012 2013 2014 2015 2016 2017
LCS-eligible heavy smokers
LCS-ineligible moderate smokers
LCS-ineligible light smokers
% Medication orders for pharmacotherapy
10
8
6
4
2
0
Guideline
2010 2011 2012 2013 2014 2015 2016 2017
LCS-eligible heavy smokers
LCS-ineligible moderate smokers
LCS-ineligible light smokers
% receiving any smoking cessation intervention(s)
45
40
35
30
25
20
15
10
5
0
Guideline
2010 2011 2012 2013 2014 2015 2016 2017
LCS-eligible heavy smokers
LCS-ineligible moderate smokers
LCS-ineligible light smokers

Appendix Figure 1. Trends in percent of receiving smoking cessation interventions among new patients by receipt of lung cancer screening referral.



LCS, lung cancer screening.

Appendix Table 1. Characteristics of New Patients (N=12,678), Aged 55–80 Years, Currently Smoking by Level of Smoking, 2010–2017

Individual-level variables	**All (N=12,678)**	**LCS-eligible heavy smokers (N=4,619)**	**LCS-ineligible moderate smokers (N=5,346)**	**LCS-ineligible light smokers (N=2,713)**	***p*-value**
	N (%)	**N (%)**	**N (%)**	**N (%)**	
Year					**<0.0001**
2010	991 (7.8)	386 (8.4)	451 (8.4)	154 (5.7)	
2011	1,228 (9.7)	478 (10.3)	537 (10.0)	213 (7.9)	
2012	1,461 (11.5)	577 (12.5)	596 (11.1)	288 (10.6)	
2013	1,900 (15.0)	729 (15.8)	765 (14.3)	406 (15.0)	
2014	2,181 (17.2)	795 (17.2)	926 (17.3)	460 (17.0)	
2015	1,958 (15.4)	688 (14.9)	842 (15.8)	428 (15.8)	
2016	1,647 (13.0)	537 (11.6)	681 (12.7)	429 (15.8)	
2017	1,312 (10.3)	429 (9.3)	548 (10.3)	335 (12.3)	
Age, years					**<0.0001**

55–64	7,695 (60.7)	2,541 (55.0)	3,495 (65.4)	1,659 (61.2)	
65–74	4,183 (33.0)	1,700 (36.8)	1,636 (30.6)	847 (31.2)	
75–80	800 (6.3)	378 (8.2)	215 (4.0)	207 (7.6)	
Female	6,635 (52.3)	2,115 (45.8)	2,902 (54.3)	1,618 (59.6)	**<0.0001**
Race/ethnicity					**<0.0001**
Missing	1,084 (8.6)	413 (8.9)	430 (8.0)	241 (8.9)	
NH white	8,959 (70.7)	3,597 (77.9)	3,775 (70.6)	1,587 (58.5)	
Hispanic	974 (7.7)	242 (5.2)	381 (7.1)	351 (12.9)	
NH black	750 (5.9)	134 (2.9)	366 (6.8)	250 (9.2)	
NH Asian	525 (4.1)	122 (2.6)	206 (3.9)	197 (7.3)	
Other	386 (3.0)	111 (2.4)	188 (3.5)	87 (3.2)	
LCS-LDCT order	204 (1.6)	123 (2.7)	58 (1.1)	23 (0.8)	**<0.0001**
Informal smoking cessation counseling or referrals to smoking cessation programs	3,429 (27.0)	1,217 (26.3)	1,452 (27.2)	760 (28.0)	0.29179
Formal smoking cessation counseling	243 (1.9)	102 (2.2)	91 (1.7)	50 (1.8)	0.17592

Medication orders for pharmacotherapy	609 (4.8)	281 (6.1)	223 (4.2)	105 (3.9)	**<0.0001**
Receiving any smoking cessation intervention(s)	4,031 (31.8)	1,486 (32.2)	1,671 (31.3)	874 (32.2)	0.53893
Pack-years categories					**<0.0001**
<10	2,536 (20.0)	0 (0)	725 (13.6)	1,811 (66.8)	
10–19	3,023 (23.8)	0 (0)	2,128 (39.8)	895 (33.0)	
20–29	2,500 (19.7)	0 (0)	2,493 (46.6)	7 (0.3)	
30–39	1,399 (11.0)	1,399 (30.3)	0 (0)	0 (0)	
40–49	1,639 (12.9)	1,639 (35.5)	0 (0)	0 (0)	
50–59	749 (5.9)	749 (16.2)	0 (0)	0 (0)	
≥60	832 (6.6)	832 (18.0)	0 (0)	0 (0)	
Pack-years, mean (SD)	26.2 (22.6)	48.3 (23.1)	16.9 (6.8)	7.1 (4.4)	**<0.0001**
Cigarettes per day, mean (SD)	14.7 (10.2)	23.3 (10.5)	12.3 (5.3)	4.5 (1.6)	**<0.0001**
Number of years smoked, mean (SD)	34.6 (13.9)	42.1 (9.2)	30.0 (13.7)	30.7 (15.5)	**<0.0001**

Note: Boldface indicates statistical significance ($p<0.05$).

LCS, lung cancer screening; NH, non-Hispanic; LDCT, low-dose computed tomography.

Appendix Table 2. ORs of Receiving Smoking cessation interventions Between New Smokers Who Received Lung Cancer Screening Referral and Those Who Did Not[a]

Effect	Informal smoking cessation counseling or referrals to smoking cessation programs OR (95% CI)	Formal smoking cessation counseling OR (95% CI)	Medication orders for pharmacotherapy OR (95% CI)	Receiving any smoking cessation intervention(s) OR (95% CI)
Receive LCS referral				
Yes vs no	**1.52 (1.08, 2.14)**	**3.58 (1.68, 7.61)**	**3.17 (2.06, 4.9)**	**2.26 (1.63, 3.12)**
Guideline change				
Post- vs pre-guideline	**1.35 (1.22, 1.49)**	**4.51 (2.98, 6.84)**	1.13 (0.96, 1.34)	**1.44 (1.31, 1.58)**
Sex				
Female vs male	1.03 (0.95, 1.12)	1.22 (0.92, 1.61)	1.11 (0.95, 1.29)	1.05 (0.97, 1.13)
Age group				
55–64 vs 75–80 years	**1.24 (1.05, 1.47)**	0.60 (0.34, 1.04)	**2.63 (1.67, 4.15)**	**1.28 (1.09, 1.5)**
65–74 vs 75–80 years	1.14 (0.96, 1.37)	0.85 (0.48, 1.51)	**1.97 (1.23, 3.15)**	**1.18 (1.00, 1.4)**
Race/ethnicity				
Hispanic vs white	0.99 (0.86, 1.14)	**0.54 (0.30,**	0.96 (0.74, 1.26)	0.95 (0.83, 1.08)

		0.95)		
Black vs white	0.89 (0.75, 1.05)	0.94 (0.54, 1.63)	1.16 (0.87, 1.54)	0.92 (0.79, 1.07)
Asian vs white	1.04 (0.86, 1.25)	1.32 (0.69, 2.54)	**0.51 (0.33, 0.81)**	0.98 (0.82, 1.17)
Other vs white	1.05 (0.86, 1.29)	2.07 (0.98, 4.38)	0.68 (0.42, 1.08)	1.4 (0.85, 1.26)

Note: Boldface indicates statistical significance ($p<0.05$).
[a]Patient demographics (age, sex, race/ethnicity) are controlled for in each model.

LCS, lung cancer screening.